Supply Chain Tokenomics - White paper

Anmool Amjad, Joséphine Laguardia, Jinane Amal

March 2025

1 Introduction

The space industry is undergoing a significant transformation driven by advancements in digitalization, automation, and emerging blockchain technologies. Traditionally, space supply chains have been characterized by complex logistics, stringent regulatory compliance, and high costs associated with component tracking, testing, and certification. However, with the rise of Web3 solutions, new opportunities are emerging to enhance transparency, traceability, and efficiency within the industry.

This white paper introduces the concept of Supply Chain Tokenomics, a blockchain-based framework that integrates decentralized technologies to address key challenges in space component management. By leveraging Non-Fungible Tokens (NFTs) and ERC-20 utility tokens, we propose an innovative approach to ensuring secure, verifiable, and cost-effective supply chain processes. Our model focuses on incentivizing industry stakeholders—manufacturers, testing laboratories, space agencies, and buyers—to contribute to a trustless and decentralized supply chain ecosystem.

We first explore the current landscape of space supply chain management, identifying key pain points such as lack of manufacturing process control, high testing costs, and inadequate tracking of automotive-grade components. We then examine how Web3 technologies, including Decentralized Physical Infrastructure Networks (DePIN) and NFT-based certification marketplaces, can provide robust solutions to these challenges. Additionally, we outline the economic incentives underpinning our system, detailing how tokenized assets can drive participation and enhance accountability across the supply chain.

By implementing a blockchain-based incentivized model, we aim to create a more resilient and transparent ecosystem that aligns with the evolving needs of the New Space economy. The subsequent sections of this white paper will delve into the technical specifications of our proposed token system, governance mechanisms, and the broader economic implications of integrating tokenomics into space industry logistics.

2 Current landscape and evaluation of Web3-digitalisation potential

The space industry is characterized by complex engineering, stringent regulatory requirements, and the need for highly reliable components. Companies operating in this sector face numerous challenges related to manufacturing, testing, tracking, and component obsolescence. To mitigate these challenges, various strategies have been adopted, each with its own advantages and trade-offs. Emerging Web3 solutions provide novel opportunities to address these issues by leveraging blockchain technology to enhance transparency, traceability, and efficiency in space operations.

2.1 Lack of control over the manufacturing process and documentation

One of the most pressing issues in the space industry is the lack of control over the manufacturing process and the difficulties in obtaining comprehensive documentation for critical components. This issue is particularly relevant when dealing with external suppliers, where a lack of transparency can lead to inconsistencies in quality, delays, and higher costs.

To address this problem, some companies, such as SpaceX, have adopted a strategy of vertical integration. By producing many of their components in-house, they maintain direct oversight over the manufacturing process, ensuring higher quality control. Vertical integration also improves supply chain resilience by reducing dependency on third-party suppliers and lowering costs by eliminating intermediary markups. However, this approach requires substantial capital investment and significant internal resources, which can limit a company's ability to quickly adapt to external technological advancements.

On the other hand, companies like Rocket Lab have opted for a different strategy, utilizing commercial off-the-shelf (COTS) components in their spacecraft. This approach allows for faster development cycles and reduces the complexity of manufacturing. However, it introduces additional challenges, such as increased testing requirements, supply chain vulnerabilities, and limited customization options. The reliance on external suppliers also makes these companies susceptible to unexpected disruptions in the supply chain, necessitating additional in-house testing to verify component reliability in space applications.

2.2 High testing costs

Another significant challenge in the space industry is the high cost associated with testing components to ensure their reliability in extreme conditions. Every component that is intended for spaceflight must undergo rigorous testing to withstand radiation, temperature fluctuations, and mechanical stresses.

To reduce testing costs, some companies have turned to radiation-tolerant COTS components specifically designed for space applications. Microchip Technology, for example, has developed radiation-tolerant microcontrollers that require less extensive individual testing, thereby accelerating development timelines and improving cost efficiency. However, these components may come with trade-offs, such as reduced customization options and performance limitations compared to fully radiation-hardened parts.

Another approach to mitigating testing costs is through system-level redundancy. Instead of investing in extensive testing for individual components, some companies deploy large constellations of satellites, accepting higher failure rates in orbit. While this approach reduces the upfront costs of testing, it increases launch expenses since additional satellites must be launched to account for potential failures.

2.3 Lack of detailed tracking in automotive-grade component

The integration of automotive-grade components into space applications presents challenges related to tracking and traceability. Unlike traditional space-grade components, which come with extensive documentation and traceability, automotive-grade components often lack detailed records regarding their manufacturing and performance history. This makes it difficult to ensure their suitability for space environments.

Pronexos has addressed this issue by implementing full traceability systems, ensuring that every component used in space applications is meticulously documented from manufacturing to deployment. This system enhances quality assurance, facilitates regulatory compliance, and enables rapid identification of defects. However, maintaining detailed traceability requires significant resources and specialized tracking systems, increasing operational complexity.

Some companies opt for a more cost-effective but limited traceability approach, which reduces operational expenses but increases risks. Without comprehensive tracking mechanisms, ensuring consistent performance and regulatory compliance becomes more challenging, potentially leading to mission failures.

2.4 Different life cycles and processes

Another persistent challenge in the space industry is managing the obsolescence of components. The life cycles of space-grade components often differ significantly from those of commercial and automotive components, making it difficult to maintain long-term availability and compatibility.

To address this issue, BAE Systems has developed the Advanced Component Obsolescence Management (AVCOM) system, which provides real-time data on component availability, lifecycle status, and alternative replacements. By proactively monitoring obsolescence, companies can plan ahead, reducing unexpected costs and minimizing the risks of supply shortages. However, implementing such a system requires an initial investment and ongoing maintenance, which may not be feasible for smaller companies.

In contrast, companies that do not engage in proactive obsolescence management often face increased non-recurring engineering (NRE) costs due to the need for redesigning and requalifying components. This leads to project delays and supply chain disruptions, as alternative components must be identified and tested at the last minute.

2.5 WEB3 solutions

Web3 technologies, particularly blockchain-based solutions, offer new ways to address some of the challenges faced by the space industry. By leveraging decentralized networks, smart contracts, and immutable ledgers, Web3 can improve transparency, reduce reliance on intermediaries, and enhance trust in space-related processes.

2.5.1 First solution: real-time record of component details using DePIN

One promising application of Web3 in the space industry is the use of Decentralized Physical Infrastructure Networks (DePIN) for real-time component tracking. By logging component data on a blockchain, companies can create digital twins or non-fungible tokens (NFTs) representing each part. This ensures immutable records of component history, reducing the risk of counterfeit parts and improving traceability. Additionally, smart contracts can automate compliance checks, ensuring that components meet regulatory requirements. However, challenges remain in terms of adoption, as some manufacturers may resist sharing proprietary data, and scalability concerns must be addressed to handle the vast amount of data generated by space components.

2.5.2 Second solution: NFT based space testing and certification marketplace

Another Web3 innovation is the creation of an NFT-based space testing and certification marketplace. In this model, space agencies and testing facilities tokenize test results and certifications as NFTs, allowing manufacturers to verify component heritage on-chain. This system provides a verifiable proof of space qualification without exposing proprietary information. It also reduces paperwork and minimizes the risk of fraudulent certifications. However, several challenges need to be addressed, such as establishing fair pricing mechanisms for access to certification data, ensuring broad industry adoption, and balancing transparency with the need for confidentiality.

3 Incentivized token economy

The space industry supply chain faces several critical challenges that hinder efficiency, transparency, and cost-effectiveness. Traditional space programs rely on highly qualified, high-reliability components, which undergo extensive testing and certification processes. However, with the emergence of New Space, there is a growing trend of using commercial off-the-shelf (COTS) components to reduce costs and improve scalability. While this approach offers advantages in affordability and production speed, it introduces new risks regarding component traceability and reliability.

To address these challenges, we propose a blockchain-based system that leverages two types of tokens: Non-Fungible Tokens (NFTs) and ERC-20 Utility Tokens (AST - Aerospace Supply Token). NFTs will be used to create a digital representation of each space component, recording its entire lifecycle, from manufacturing to testing and eventual deployment. The AST token will serve as a utility and incentive mechanism, rewarding participants for their contributions to supply chain transparency and verification.

This token-based approach ensures that key supply chain actors such as manufacturers, testing laboratories, space agencies, and buyers have a direct incentive to contribute reliable information. By integrating smart contracts, this system automates verification processes, reducing the reliance on centralized authorities while maintaining high levels of trust.

Our objective is to create an incentivized economy where participants are rewarded for their contributions, ensuring that space components meet required safety and quality standards while maintaining the cost-effectiveness that New Space demands. The following sections will detail how this economy is structured, how the tokens interact, and how different actors engage with the system.

3.1 Initial Set-Up and Blockchain choice

The initial pilot of this system will likely be launched in collaboration with a national space agency such as CNES or DLR, as these institutions play a crucial role in ensuring compliance with industry standards. Given the need for transparency, immutability, and accessibility, the blockchain infrastructure will be public rather than private. A public blockchain ensures that all participants including manufacturers, laboratories, and buyers can independently verify data without reliance on a central authority, enhancing trust across the supply chain.

The administration of the platform will be structured around a decentralized governance model, where key stakeholders including space agencies, manufacturers, and independent organizations will engage in decision-making through a staking mechanism. This governance structure prevents a single entity from gaining unilateral control over the ecosystem, maintaining fairness and ensuring that updates to the protocol are agreed upon collectively.

In terms of infrastructure, the hardware requirements for participants will primarily involve secure data logging infrastructure, as well as access to blockchain nodes that facilitate transaction verification. Manufacturers and laboratories will need to integrate digital wallets and blockchain tools into their existing workflows, but the system is designed to be cost-effective, minimizing upfront investments for new adopters through the use of lightweight blockchain clients.

Financing the system

The development and deployment of the blockchain-based supply chain system will require an initial investment to cover infrastructure, development, and operational costs. The national space agencies (CNES, DLR) may provide partial funding for the technical deployment and governance framework but will not issue tokens or control token distribution. Instead, the financial structure of the AST ecosystem will be independent from government funding and will rely on the following sources: Initial Coin Offering (ICO) and Private Investment: The AST token supply will include an initial allocation for an ICO or private sale, allowing early investors and industry stakeholders to acquire tokens before deployment. This method ensures that financing comes from market participants rather than centralized government sources.

Partnerships with Space Industry Stakeholders: Private entities, including New Space companies, satellite manufacturers, and component suppliers, will contribute to financing the system in exchange for early access to the NFT-based certification system and other premium services.

Platform Fees and Transaction Costs: A percentage of transactions involving AST tokens, including payments for certification services and access to NFT data, will be used to fund ongoing system maintenance and future development. This self-sustaining model ensures long-term viability.

By structuring financing in this way, the system avoids reliance on off-chain collateralized funds from government agencies while ensuring that funding is decentralized, transparent, and sustainable.

3.2 Community participants

The ecosystem consists of several key participants, each with a distinct role in maintaining data integrity and economic stability. Manufacturers are responsible for issuing NFTs corresponding to the components they produce, ensuring that metadata such as origin, materials, and technical specifications are accurately recorded. Testing laboratories play a vital role by verifying the quality of components, conducting rigorous certification tests, and updating the associated NFTs with their findings. Space agencies oversee the entire process, ensuring compliance with safety regulations and enforcing accountability within the ecosystem. Finally, buyers, including New Space companies, satellite manufacturers, and mission operators, use the NFT records to verify the authenticity and performance history of a component before making a purchase decision.

Finally, this well-defined structure ensures that all stakeholders contribute to improving supply chain efficiency, while fostering a secure and transparent exchange of components.

3.3 Tokenomics and economic incentives

The AST token is central to the incentivization mechanism of this system. It is designed to reward key participants who contribute reliable and verifiable data to the blockchain, ensuring that supply chain transparency is maintained. Manufacturers earn AST tokens when they create NFTs for their components and maintain up-to-date records. Testing laboratories receive AST rewards for conducting verifications and adding test results to NFTs, thus reinforcing trust in the system. Buyers can use AST tokens to access premium certification details or pay for priority testing services, ensuring a seamless economic loop between different actors.

This system aligns financial incentives with verifiable contributions, ensuring that accurate information is continuously integrated into the blockchain. By rewarding truthful disclosures and penalizing fraudulent activity, the ecosystem naturally filters out unreliable data sources, leading to a self-sustaining, fraud-resistant economy.

3.4 Monetary policy and stability

To ensure long-term economic stability, the AST token follows a carefully designed monetary policy. The total supply of AST will be capped, preventing uncontrolled inflation and maintaining the token's value over time. Additionally, a burn mechanism will be implemented, where a percentage of AST used for certification services is permanently removed from circulation, ensuring scarcity and maintaining economic balance. Participants will have the ability to exchange AST for fiat currency or stablecoins through integrated on/off-ramp mechanisms such as decentralized finance (DeFi) platforms and centralized exchange partnerships. This ensures that participants can seamlessly transition between the token economy and real-world financial markets, increasing adoption and usability.

As adoption expands, the system will integrate Layer-2 scalability solutions such as rollups, reducing transaction fees and improving efficiency. This ensures that the platform can handle increasing transaction volumes without compromising speed or cost-effectiveness.

3.5 Reward and incentive levers

Beyond basic transactions, the system includes additional incentives to encourage participation and long-term engagement. Staking rewards allow participants to lock AST tokens in smart contracts, earning additional tokens while securing the ecosystem and participating in governance decisions. This ensures that stakeholders who contribute to the long-term success of the system receive proportional benefits.

To drive early adoption, airdrops and grants will be distributed to manufacturers and testing laboratories that integrate their operations into the blockchain system. This initial boost ensures widespread adoption and incentivizes entities to transition from traditional supply chain management to a blockchain-based model.

(A) Role	(B) Desired Behaviors	(C) Frictions to Desired Behaviors	(D) Incentive Mechanisms	(E) Supply Effect	(F) Unintended Incentives	(G) Prevention mechanics
Who are the entities involved in this token economy?	**What kind of actions do we want to encourage? social, psycological and technical actions**	**Could anything prevent or discourage these actions from being achieved?**	**Propose an incentive mechnism (reward, staking, airdrop, exclusive access, etc.)**	**What effect does this have on the token supply? (Burnt, Locked, Lost, Affect another token, etc)**	**Any unexpected behaviours arising from our proposed incentive mechanics from D?**	**How can we prevent these negative incentives (penalties, bans, another incentive, etc)**
Manufacturers	Register components as NFTs and maintain accurate metadata	High adoption costs, lack of technical knowledge	Earn AST tokens for registering components and updating metadata	Tokens are earned from system rewards, but partially locked for ecosystem stability	Manufacturers might attempt to register low-quality components for rewards	Loss of credibility, temporary ban from registering components
Testing Laboratories	Conduct and verify component certifications, updating NFTs with test results	Lack of incentives, reluctance to use blockchain systems	AST rewards for providing verifiable certifications	AST tokens issued for valid certifications; staking required for credibility	Labs could falsely validate certifications to earn AST	Penalties for false certifications, reduced AST rewards
Space Agencies	Supervise compliance and enforce standards	Bureaucratic resistance, slow policy updates	Access to governance participation and decision-making in token system	AST used for governance is locked while voting is active	Agencies might exert too much control over governance, limiting decentralization	No governance access for non-compliant agencies
Buyers	Verify NFT records before purchasing components, participate in governance	Unclear benefits, reluctance to use token-based systems	Discounts or exclusive access to high-quality component data for AST holders	Payments in AST can be burned to reduce supply over time	Speculative buying of AST could lead to market manipulation	Buyers who misuse certification data may face restrictions in system access

Figure 1: Incentive Mechanisms

A reputation-based rewards system will also be implemented, where entities that consistently provide high-quality contributions such as reliable testing laboratories receive periodic AST bonuses. This approach strengthens trust in the ecosystem by recognizing and rewarding participants who maintain high data integrity standards.

With this framework, the NFT and AST ecosystem creates a transparent, fraud-resistant, and incentive-driven economy for the New Space supply chain. The next chapter will present the technical specifications of these tokens.

4 Technical Specification of Tokens

This chapter defines the technical specifications of the NFT-based space component tracking system and the AST utility token, ensuring compliance with ERC-721 and ERC-20 standards.

4.1 NFT Specification (Component Digital Twin - ERC-721)

Simple Summary

An ERC-721 non-fungible token (NFT) that serves as a digital twin for a space component, tracking its lifecycle, certifications, and ownership history in an immutable and verifiable way.

Abstract

This standard defines an ERC-721 non-fungible token (NFT) that represents a digital twin of a physical space component. Each NFT uniquely identifies a component in the supply chain and stores manufacturing details, test results, and ownership history. The NFT ensures real-time traceability and authenticity verification of components used in space missions.

Motivation

The space industry faces challenges in tracking and verifying components across the supply chain. By using ERC-721 NFTs, we can create an immutable record of a component's lifecycle, preventing fraud and improving efficiency. The NFT:

- Ensures provenance and authenticity of components.
- Allows automated verification of test certifications.
- Enables secure ownership transfers between manufacturers, testing labs, and buyers.

Specification

The NFT contract must implement the ERC-721 standard and include the following functions:

1. Minting an NFT for a Space Component

function mintComponent(address to, string memory metadataURI) public returns (uint256);
to → Address receiving the NFT.
metadataURI → Stores metadata (manufacturing details, certifications, test results).

Returns → Unique token ID assigned to the component.

2. Updating Component Metadata

function updateMetadata(uint256 tokenId, string memory newMetadataURI) public;

tokenId → The NFT representing a specific space component.

newMetadataURI → Updated metadata (e.g., after a new test result is added).

3. Transferring Ownership of a Component

function transferOwnership(address from, address to, uint256 tokenId) public;

from → Current owner.

to → New owner.

tokenId → NFT representing the component being transferred.

4. Approving a Third Party to Manage an NFT

function approve(address approved, uint256 tokenId) public;

approved → Address allowed to manage the NFT.

tokenId → NFT representing the component.

5. Securely Transferring an NFT

function safeTransferFrom(address from, address to, uint256 tokenId) public;

from → Current owner.

to → New owner.

tokenId $\rightarrow$ NFT being transferred.

4.2 ERC-20 Token Specification (AST - Aerospace Supply Token)

Simple Summary

An ERC-20 fungible token used to incentivize participation in the space component supply chain, enabling payments for certifications, staking for governance, and secure transactions within the ecosystem.

Abstract

The Aerospace Supply Token (AST) is an ERC-20 fungible token designed to incentivize testing laboratories, manufacturers, and component buyers to participate in the blockchain-based supply chain system. AST facilitates rewarding verifiable contributions, accessing premium certification data, and engaging in governance decisions.

Motivation

The space supply chain lacks transparent and automated incentives for ensuring component quality. AST introduces economic incentives to:

- Reward testing labs for adding verified certifications.
- Encourage manufacturers to maintain accurate NFT records.
- Allow buyers to access critical certification data through tokenized payments.

Specification

The AST contract must implement the ERC-20 standard and include the following functionalities:

1. **Standard ERC-20 Token Transfers**

function transfer(address to, uint256 amount) public returns (bool);

to $\rightarrow$ Address receiving AST tokens.

amount $\rightarrow$ Number of tokens being transferred.

2. **Approving Token Spending by a Third Party**

function approve(address spender, uint256 amount) public returns (bool);

spender $\rightarrow$ Address allowed to spend tokens.

amount $\rightarrow$ Approved token amount.

3. **Burning AST to Reduce Supply**

function burn(uint256 amount) public;

amount $\rightarrow$ Number of AST tokens permanently removed from circulation.

4. **Staking for Governance Participation**

function stakeTokens(uint256 amount) public;

amount $\rightarrow$ Number of AST tokens locked for governance.

5. **Automated Payments and Transfers**

function transferFrom(address from, address to, uint256 amount) public returns (bool);

from $\rightarrow$ Sender's address.

to → Receiver's address.

amount → Number of AST tokens being transferred.

6. Minting New AST Tokens

function mint(address to, uint256 amount) public;

to → Address receiving newly minted AST tokens.

amount → Number of tokens created.

Note: This function should be restricted to authorized roles if used.

References

[1] Investopedia. ”How SpaceX Reinvented the Rocket Launch Industry.” Available at: `https://www.investopedia.com/news/how-spacex-reinvented-rocket-launch-industry/`.

[2] Aviation Week. ”Why the U.S. Space Industry is So Obsessed with Vertical Integration.” Available at: `https://aviationweek.com/space/commercial-space/why-us-space-industry-so-obsessed-vertical-integration-0`.

[3] Military Embedded Systems. ”Tapping COTS Components for Small Satellites.” Available at: `https://militaryembedded.com/comms/satellites/small-tapping-cots-components`.

[4] Microchip Technology. ”COTS to Radiation-Tolerant and Radiation-Hardened Devices.” Available at: `https://www.microchip.com/en-us/solutions/aerospace-and-defense/products/microcontrollers-and-microprocessors/cots-to-radiation-tolerant-and-radiation-hardened-devices`.

[5] Pronexos. "Quality, Traceability Security in Space." Available at: https://www.pronexos.com/space/quality-traceability-security/.

[6] BAE Systems. "AVCOM: Aerospace Defense Intelligence." Available at: https://www.baesystems.com/en-us/our-company/inc-businesses/intelligence-and-security/capabilities-and-services/avcom.

[7] Sourceability. "Proactive Obsolescence Management in Aerospace and Defense Industries." Available at: https://sourceability.com/post/proactive-obsolescence-management-in-aerospace-and-defense-industries.